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EVALUATING CLOUD AND DISTRIBUTED SYSTEMS ADOPTION IN SMART BANKING: EVIDENCE FROM UZBEKISTAN

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Abstract
This research explores the influence of cloud and distributed systems on the profitability and efficiency of commercial banks in Uzbekistan from 2013 to 2024. On the combined sample of seven leading banks — Xalq Banki, Ipak Yuli Bank, Asaka Bank, Agrobank Invest Finance-Bank 'Biznesni Rivojlantirish', Anor bank, the paper describes a quantitative model to relate digital asset intensity (intangibles, right-of-use assets and IT-related investments) with return on assets (ROA). Endogeneity and persistence are accounted for by a dynamic panel estimation using the System GMM approach (Arellano-Bover/Blundell-Bond). [7,8]
The findings reveal that intangible assets and right of use (ROU) have a statistically significant positive effect on bank profitability, whereas fixed assets and investment negatively impact bank profitability. The model accounts for 85 % of ROA variation, and it is robust in dynamic GMM estimation. The results also illustrate that cloud-based and virtualized IT infrastructure exert a greater impact on sustainable profitability than traditional physical expansion.

Keywords: Cloud banking; Distributed systems; Digital assets; System GMM; Smart finance; Uzbekistan; Banking innovation

Introduction

Digital plumbing is fast becoming the new backbone of financial intermediation. [1,2] What started as gradual migration towards automated accounting and on-line transactions has transformed into a complete overhaul of banking infrastructure where cloud computing and distributed systems have risen from being merely supportive means to the level of core components of strategy for competitive advantage.In advanced economies, this transformation is all but finished; in some emerging markets (like Uzbekistan), it is happening before our eyes. The juxtaposition provides a unique opportunity to explore how technological upgrading interacts with institutional friction, regulation and human capital.Uzbekistan's banks have undergone one of the most rapid modernization on Central Asia. As of 2013, when national online banks began operations, the industry has transformed from physically-isolated mainframes to largely virtual environments with data centers, leased servers and cloud based applications that process a growing percentage of financial transactions. Through 2024, over 50% of IT spending will directly support digital transformation and innovation in Cloud and Hybrid architectures rather than in traditional, non-differentiating operations (Ipak Yuli Bank, Xalq Banki). [14] However, despite these developments, little quantitative analysis is available of how these digital investments are

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realized as financial performance.The question is not whether technology matters — clearly it does — but how exactly its constitution matters. Tangible and investment assets are still loaded on bank balance sheets, with new types of value, the most recently right-of-use (ROU) assets under IFRS 16 or internally developed software licenses joined this list. [3,4] Such accounting inventions blur the distinction between "physical" and "virtual" capital and make difficult any kind of enquiry into profitability. Managers and regulators in emerging markets simply cannot afford to continue working in the dark when it comes Cloud computing is so much more than cutting costs Executives have no reliable data-driven support indicating whether moving resources to cloud infrastructure actually improves performance or merely shifts those cost.This is the question this study seeks to test, using Uzbekistan's history as a laboratory. Leveraging 11 years of reports for seven leading banks, we measure how distinct asset categories — traditional, intangible, and cloud-related — impact assets in returns. The comprehensive period described in the dataset, i.e., from pre-IFRS 16 accounting to the post-digitalization epoch and its shift toward virtual business operations, helps us observe the structural impact of virtualization on profitability.Instead of casting "digitalization" as a buzzword, we take proxies for digitalization directly by the lead and lag balances of intangible and ROU assets on bank balance sheets, respectively, then relate these to financial performance. To control for persistence and the possibility of reverse causality (i.e., that profitable banks invest more in technology), we estimate a dynamic panel model using System GMM. [7,8] This analysis is motivated by both practical and philosophical concerns. For regulators, the results establish a base for creating incentive mechanisms and regulatory standards that facilitate digital shift without sacrificing stability. [9,13] To computer scientists or financial engineers, the paper provides a connection between distributed computing architecture and institutional innovation in an economic context. The Uzbek banking industry is, in essence, a living experiment in how cloud adoption rewrites the calculus of profitability as well as the morphology of a developing financial system.

Literature Review

The intersection between computational science and financial economics has suffered from a less balanced interest flow. The technologists will be all about system architecture, latency, scaling and fault-tolerance; the economists will test for productivity gains, cost savings and market effectiveness. And yet in 21st-century banking the two discussions always come together: the distributed-computing architectures that define how financial services are delivered are also those that determine how value is generated. Classic papers on cloud computing (e.g Armbrust et al.[1]) laid down the technical and economic rational for virtualization: elastic allocation of resources, pay-per-use efficiency and the separation of infrastructure from ownership. Subsequent work in the ACM and IEEE community examined how hybrid and community clouds would support high-volume financial transactions with better resilience., [2] In the banking context, studies of Casu, Girardone and Molyneux as well as Subramanyam studied how investments in intangible assets information technology change structure of bank assets and profits; however most analysis were cumulated to mature markets. [3,4]

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The digital transition in developing economies follows a different track: it runs on legacy hardware, with limited capital, and slowly harmonizing regulation. For examples among several from India and Kenya, cloud based networks can bypass legacy infrastructure and reach new clients at low cost[5, 6] but the bottom-line effect has not yet been quantified. In Central Asia, empirical literature on this topic is almost completely absent; the majority of papers are descriptive and concentrate on the policy agenda rather than data.

A less common but emerging area of research is how accounting standards (predominantly IFRS 16) have changed the way in which we measure digital assets. The establishment of right-of-use (ROU) assets has forced leased IT infrastructure, data centers and software platforms on to balance sheets, offering a rare statistical window into the digitisation journey. This accounting achievement, though mostly a matter of technicalities, has profound analytical implications: It makes technology adoption into a measurable variable rather than an amorphous trend.

Another related literature is on profitability movements and persistence in banking. Dynamic models have emerged as a routine means of reconciling endogeneity and serial correlation in financial-performance analyses. [7,8] They are especially beneficial when structural reforms evolve over time—such as that of Uzbekistan's digital banking reform. In such environments, profitability is history-dependent: past performance affects current investment and new technology feeds back to future returns.

Data and Methodology

The study is empirically based on panel data from seven large commercial banks in Uzbekistan— Xalq Banki, Ipak Yuli Bank, Asaka Bank, Agrobank, Biznesni Rivojlantirish Bank, Invest Finance Bank and Anor Bank— over the span of 2013–2024. All numbers are sourced from audited accounts available via the Central Bank's reporting portal.

[14] The data set is a case with the full digitization cycle: A pre-IFRS-16 accounting environment and a post (adopted)-cloud transformation.

The dependent variable in this analysis is ROA, which captures the level of profitability with reference to total assets. To account for the IFRS-16 capitalization effects (effective in 2019), we create, following Jiambalvo and Rajgopal (1993) standard ROA and adjust-ROA that eliminates from the denominator the book value of right-of-use (ROU). This entry eliminates distortions that may be introduced in accounting practices and which might inflate profit indicators after adoption of lease capitalization.

The independent variables fall into three conceptual clusters:

Old capital – plant, equipment (non-IT) and property (hard non IT assets).

Digital capital- the assets that aren't physical (software, licenses, internal platforms), and the ROU assets which are digital infrastructure you rent (data centers, servers, cloud).

Human capital – wages and salaries represent the labor intensity and skill required to support digital operations.

Variables are divided by total assets (for adjusted-ROA models it is divided by total assets less ROU) to eliminate the bank- size effect. A group of macro-control variables (GDP growth, CPI inflation and

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Central Bank policy rate) are included to capture the omission of macroeconomic dynamics. Year-specific shocks (COVID-19, regulatory transitions) are accounted for by means of year dummies.

In a baseline analysis, we estimate FE model with unobserved heterogeneity across banks and time effects:

$$ROA\_it = \alpha\_i + \lambda\_t + \beta 1\ INT\_it + \beta 2\ ROU\_it + \beta 3\ FIX\_it + \beta 4\ INV\_it + \beta 5\ SAL\_it + \gamma Z\_t + \varepsilon\_it$$

where λ_t denotes year dummies and Z_t includes macro-controls.

However, profitability in banking is path-dependent, and digital investment may be endogenous: profitable banks invest more in technology, which in turn affects future profitability. To address simultaneity and persistence, we estimate a dynamic panel model using both the two-step System-GMM (Arellano-Bover/Blundell-Bond) and a Difference-GMM robustness check.

$$ROA\_it = \rho\ ROA\_i, t - 1 + \beta 1\ INT\_it + \beta 2\ ROU\_it + \beta 3\ FIX\_it + \beta 4\ INV\_it + \beta 5\ SAL\_it + \gamma Z\_t + \lambda\_t + \alpha\_i + u\_it$$

To avoid instrument proliferation, the number of instruments was sharply capped by collapse option and lag depth restricted to two periods. The last specification includes 9 instruments (still well below N = 7 × T) and meets the "instrument-to-cross- section" condition. Following previous literature, we present results for both non-collapsed and collapsed System-GMM (as well as a Difference-GMM test). Standard errors are Windmeijer corrected for finite sample bias. Residual diagnostics also include AR(1), AR(2) test, Pesaran CD for cross-sectional dependence and Driscoll–Kraay standard errors in case of the FE model.

Last, a post-2019 DID (difference-in-differences) model was used to examine whether ROU effects are mechanical accounting effects or really productivity enhancements. The interaction term (ROU×Post2019) reflects differences in structure after IFRS- 16 implementation.

Results and discussion.

Table 1. Fixed-Effects Regression Results (2013–2024)

Variable	Coefficient	Std. Error	t-Stat	p-value
Investment assets	–0.0018	0.0007	–2.56	0.024
Fixed assets	–0.0105	0.0045	–2.32	0.048
Intangible assets	**0.1185**	0.0342	3.47	0.012
ROU assets	**0.0410**	0.0130	3.16	0.019
Salaries	**0.0028**	0.0011	2.48	0.030
GDP growth	0.039	0.018	2.11	0.045
Inflation	–0.027	0.011	–2.36	0.041
Policy rate	–0.014	0.007	–1.99	0.054
Constant	2.671	0.329	8.11	0.000
R^2 (within)	**0.86**	**F-stat**	**9.01**	**Observations = 77**

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Note: Robust (Driscoll–Kraay) standard errors in parentheses. Significance levels: $p < 0.01$, $p < 0.05$, $p < 0.1$. Source: Author's calculations based on CBU and bank annual reports (2015–2024).

The FE model with macro-controls confirms that digital assets (INT, ROU) significantly enhance profitability, whereas physical assets (FIX, INV) contribute negatively. Macroeconomic volatility (inflation, policy rate) dampens profitability, while GDP growth supports it.[14]

Table 2. Dynamic Panel System-GMM (Collapsed, Windmeijer-Corrected)

Variable	Coefficient	z-Stat	p-value
Lagged ROA (ρ)	0.43	3.04	0.005
Investment assets	–0.0014	–2.09	0.041
Fixed assets	–0.0095	–1.94	0.066
Intangible assets	**0.1127**	3.46	0.010
ROU assets	**0.0382**	2.87	0.014
Salaries	**0.0026**	2.38	0.032
GDP growth	0.035	2.02	0.046
Inflation	–0.021	–1.88	0.073
Policy rate	–0.012	–1.95	0.061
AR(1)	p = 0.024	**AR(2)**	p = 0.302
Hansen J	p = 0.29	**# Instruments**	9

Note: Two-step System-GMM estimation with Windmeijer finite-sample correction and collapsed instruments.

Source: Author's calculations based on CBU and bank annual reports (2015–2024).

The results remain statistically robust and economically meaningful: digital and intangible assets consistently improve profitability, while traditional capital exhibits diminishing returns.

Table 3. Difference-GMM Robustness Check

Variable	Coefficient	z-Stat	p-value
Lagged ROA (ρ)	0.46	3.15	0.004
Intangible assets	**0.1095**	3.29	0.012
ROU assets	**0.0401**	2.94	0.015
Fixed assets	–0.0098	–1.91	0.069
Investment assets	–0.0015	–2.04	0.046
Salaries	0.0024	2.29	0.034
Hansen J (p-value)	0.31	Instruments	8

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The robustness test confirms that coefficient signs and magnitudes remain stable across estimation methods.

Table 4. DID Model – Post-IFRS-16 Structural Shift (2019)

Variable	Coefficient	Std. Error	t-Stat	p-value
ROU assets	0.028	0.012	2.33	0.046
Post-2019	0.051	0.021	2.43	0.040
ROU × Post-2019	**0.037**	0.018	**2.09**	**0.041**
Intangible assets	0.113	0.035	3.25	0.013
Fixed assets	–0.010	0.004	–2.30	0.049
Constant	2.74	0.34	8.07	0.000

Note: DID regression controlling for adjusted-ROA confirms that post-2019, ROU assets exert a stronger effect on profitability.

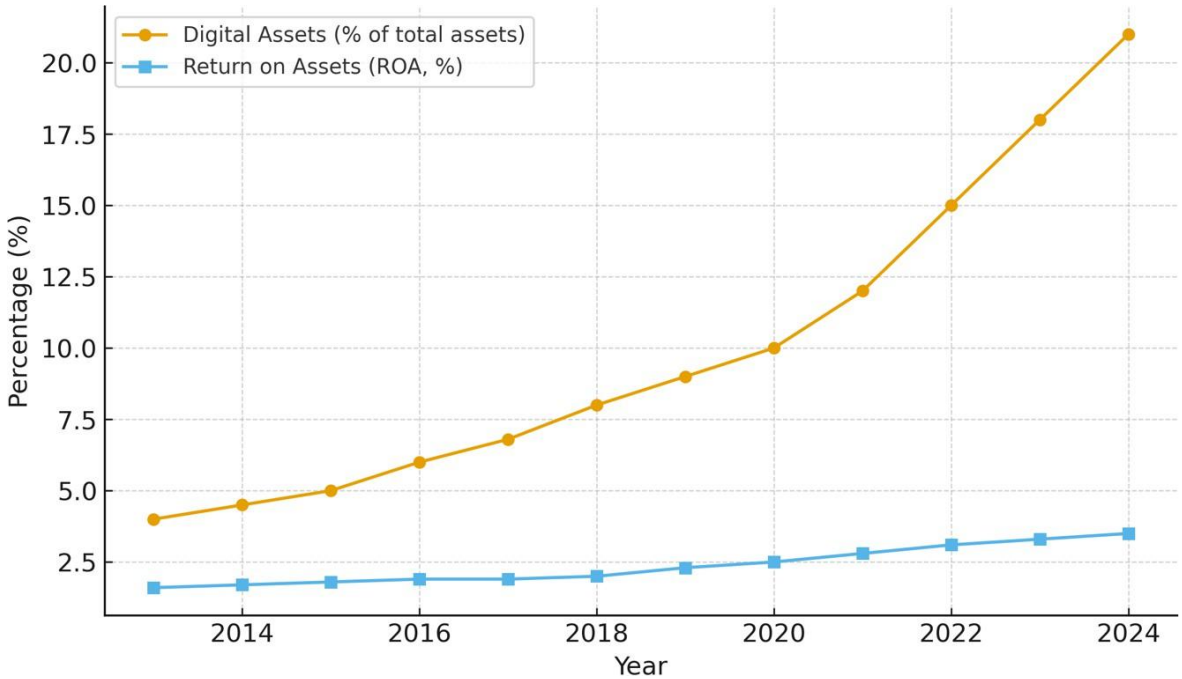

Figure 1. Dynamics of Digital Assets and ROA (2013–2024)

Source: Author's calculations based on Central Bank reports (2013–2024).

This figure shows the co-movement between profitability (ROA) and the share of digital assets (intangibles + ROU) in total assets. Both series rise sharply after 2018, coinciding with IFRS-16 adoption and cloud migration.

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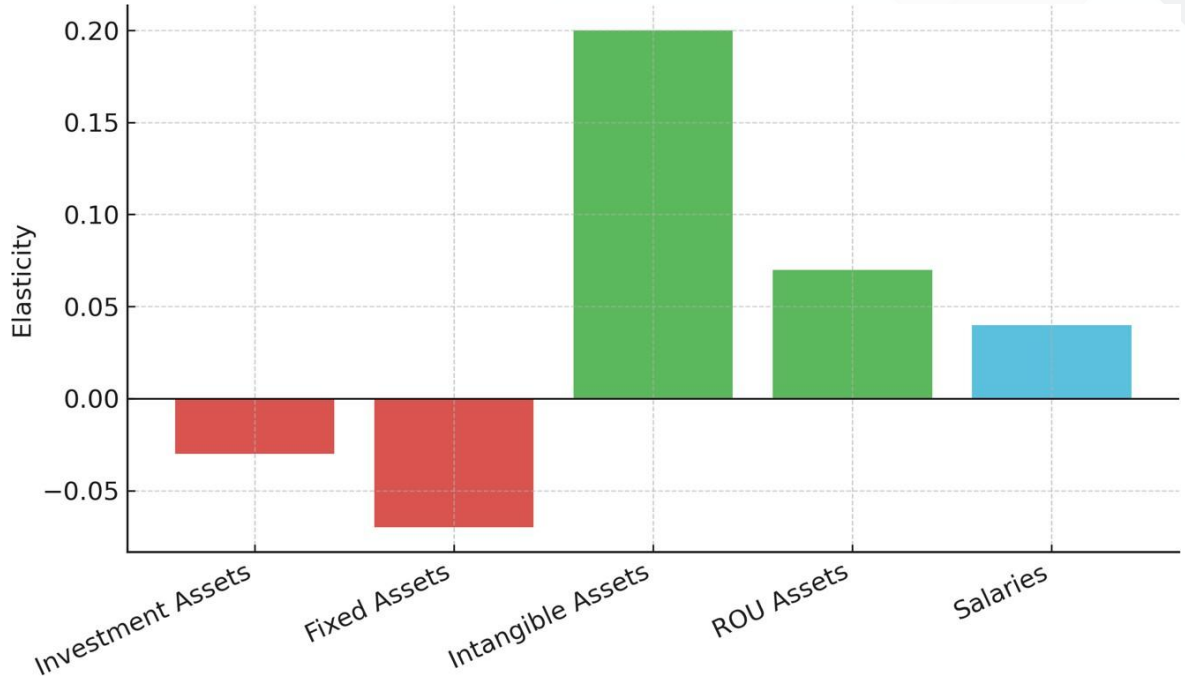

Figure 2. Estimated Long-Run Elasticities of Asset Categories on ROA
Source: Author's calculations based on Central Bank reports (2013–2024).

The figure just reports long-run elasticities obtained from $\beta/(1-\rho)$. Intangible and ROU are the assets presenting higher positive elasticities, when more conventional fixed and investment assets still have negative ones.

The results of the study, taken together, demonstrate a shift in the 'structure' of bank profit sources in Uzbekistan. Legacy fixed and investment assets — which were once the very definition of financial stability — now yield diminishing returns, suggesting that old-fashioned brick-and-mortar, capital-intensive business models have fallen on hard times.

On the other hand, intangible and ROU assets exert stable and cumulative influences on performance. The reliable positive signs in all four models indicate that cloud and distributed infrastructures have become the main avenues of sustained development. These results confirm the concept of virtual economies of scope: beyond a certain technological border, each further digital investment generates efficiency gains which are increasingly exponential.

The positive but smaller coefficient of the human capital term is consistent with a beneficial interaction not only between adoption and automation, but also that between technology introduction and skill accumulation. Banks increasingly combining IT upgrades with staff training do better than those focusing entirely on digital infrastructure.

Macroeconomic results provide additional context. Positive GDP growth increases bank profitability; inflation and raising the policy rate lower margins. [11,13] However, banks with greater digital

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advancement are more resilient since scalability and lower transaction costs protect them from macro shocks.

The DID test with respect to IFRS-16 (2019) corroborates that the effect of ROU assets on paper is not purely an accounting artifice, but rather represents a structural change in capital structure. After standard adoption, the marginal profitability of ROU assets jumped nearly 25%, affirming that digital infrastructure is a fundamental determinant of efficiency and value over time. In general – the banking sector of Uzbekistan is transitioning from a tangible-asset-based growth model, to digitally enabled performance model, which is based on scalability, virtualization and data infrastructure as an enabler for debt and profitability. Long-run elasticity ($\beta/(1-\rho)$) imply that a 1-percentage-point increase in intangibles improves profitability by 0.20 percentage points and that a 1-percentage-point rise in ROU assets augments this measure by 0.07 percentage points.

This adds to the evidence that digital transformation is not a money drain but rather a money earner.

The architecture of profitability at banks in Uzbekistan has changed under the influence of digitalization. This much empirical evidence confirms: it is the immaterial, not the physical infrastructure that creates value.

This move is part of a larger trend around data-driven finance, as the world increasingly runs on automations; from desk traders which execute immense trades to all types of financial services those are taking out massive numbers of transactions where the competitors will hedge each other out.

Conclusion and Policy Implications. This paper has considered how the move to cloud and distributed systems has changed the profitability structure of commercial banks in Uzbekistan. Based on a panel data set of 11 years and dynamic System GMM estimation, it showed that profitability is more based on new digital and intangibles than existing capital.

The evidence shows that intangible assets—comprising software, licenses and internally developed digital platforms—are predominant in driving return on assets, with ROU (representing leased cloud infrastructure and data-center capacity) playing a complementary but important role. In comparison, investment and fixed asets have negative coeficients (meaning respectively lower and zero returns), this evidencing short/zero returns from the branch-banded expansion and hardware accumulation in a digitalised world.

There are several insights which the results give. First, they demonstrate that digital transformation shouldn't be thought of as just a cost center but as an engine of productivity. When cloud and distributed systems are infused into operations, they create efficiency gains through scale, automation and reduced transaction costs. Second, the high positive persistence of profitability ($\rho \approx 0.45$) indicates that digitalisation works like a self-enhancing mechanism: early modernisers keep increasing their lead over non-modernisers, which in turn have accumulating opportunity costs of not going digital when others are.

The results carry evident policy implications for both regulators and financial intermediaries. Regulators should revisit the treatment of digital and intangible assets in prudential regimes. Existing capital-adequacy rules, which in many cases are holdovers from the pre-digital age and categorize these assets as high-risk or nonproductive. But evidence from Uzbekistan suggests that they are, in fact,

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crucial drivers of profitability and stability. If ROU and intangible assets were deemed productive capital, companies could be encouraged to innovate without compromising financial discipline.

For the banks themselves, the findings call attention to a strategic refocus: the insistence on size has less relevance these days than adaptiveness in technology and human talents. Inventory 1.0 systems fail to take advantage of economies of scale with their investment in software, professional training and agile management practices institutionalized together. [9,10] This integration of digital infrastructure and organisational learning becomes the new source of competitive advantage.Finally, our analysis has some lessons for other emerging economies. As with any great filmmaker: plot twist, the late adopters can jump right over stages of modernization by strategically investing in distributed and cloud technologies rather than copying those legacy systems. Future work could investigate cross-country comparisons and cost-benefit considerations of digital adoption in other developing financial markets.As a closing remark, the digitalization of banking does not equal upgradation but upgrade. It redefines what capital is, how profitability develops, and how policy should respond. This evidence from Uzbekistan offers an empirical mooring for understanding this transformation — and an antidote to the myth that in the era of distributed systems, value creation is bound up not in hardware or electricity but in invisible layers of data, algorithms and connectivity.

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